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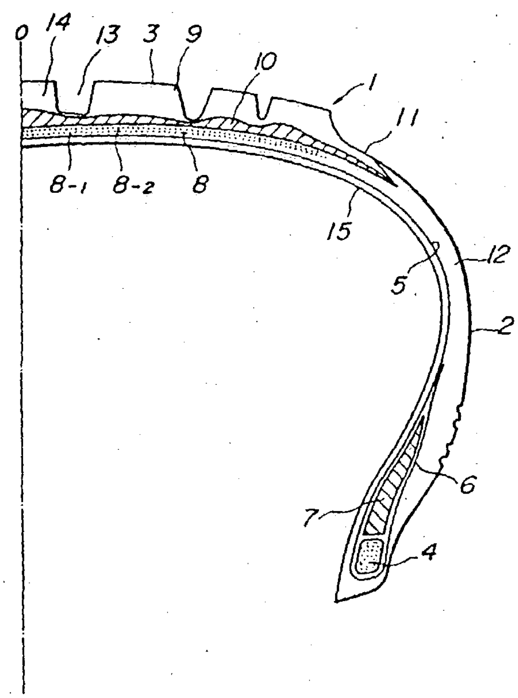
(54) Pneumatic radial tire

(57) The tread is composed of at least two rubber layers in the direction of the thickness thereof, in which an inner rubber layer (10) has a dynamic modulus (E') of 100-250 kg/cm^2 and an outer rubber layer (9) has a dynamic modulus (E') of 70-150 kg/cm^2 and a loss tangent (tan δ) of at least 0.25, and the ratio of the dynamic modulus of the inner rubber layer to that of the outer rubber layer is at least 1.15.

The rubber in each layer may be based on butadiene-styrene copolymer. The average thicknesses of the inner and outer layers may be 2.0 mm and 8.0 mm respectively.

The tire, for passenger cars, gives an improved steering response during high-speed running.



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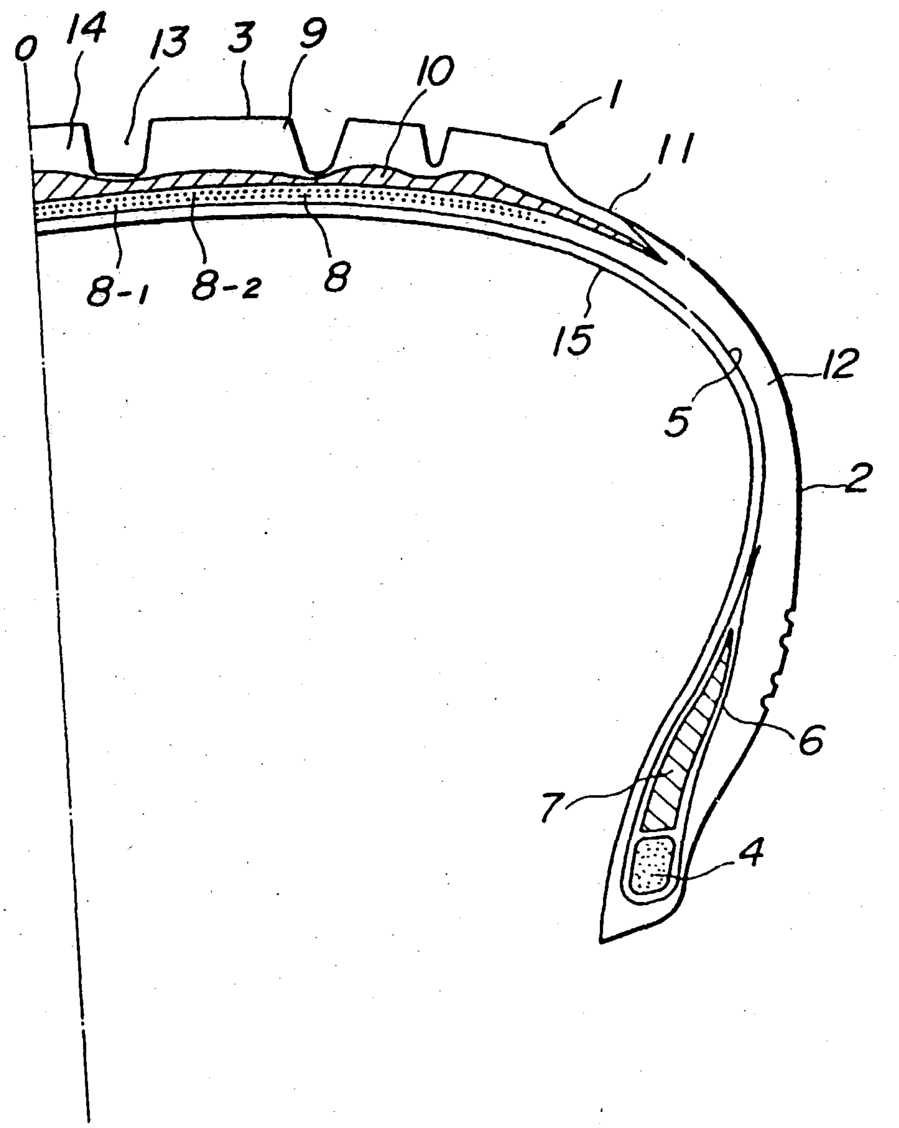

SPECIFICATION

Pneumatic radial tire

This invention relates to a pneumatic radial tire having a good high-speed running performance, and more particularly to a pneumatic radial tire for passenger cars having an improved steering response during high-speed running.

In general, tire tread rubbers are required to have characteristics such as wet resistance, cut resistance and slip resistance, and also to have a rolling resistance which is closely related to the fuel consumption of an automobile vehicle. Among these characteristics, the slip resistance (wet skid resistance, etc) in particular tends to conflict with the requirement of the rolling resistance, so that the use of a rubber advantageous for the former becomes disadvantageous for the latter, and vice versa. In order to improve such conflicting characteristics simultaneously, there have been developed tread rubers having a composite structure such that a rubber having an excellent wear resistance is used in the portion especially exposed to wear during the running and a rubber having suitable rolling resistance characteristics is used in the other portions.

With respect to the composite structure of the tread rubber, in addition to the above, as described in, for example, United States Patent Specification no. 3,759,306 there is proposed a structure wherein a rubber having a considerably high stretch modulus is used in a base portion bounded by bottoms of tread grooves for preventing the wrenching out of tread ribs from their root during the running of a passenger tire at a high speed and a rubber having an excellent wear resistance and a relative low stretch modulus is usually used in portions exposed to wear.

The present invention is different from the above mentioned prior composite structure, and aims to largely improve the steering response at high-speed of radial tires by use of a particular composite tread structure comprising an inner layer having a suitable high modulus of elasticity in portions forming the base such as ribs, blocks or lugs cast into the tread portion, and an outer layer arranged on the inner layer and having a particularly improved gripping property on the road surface and a modulus of elasticity in a given ratio with respect to the inner layer.

According to the invention, there is provided a pneumatic radial tire, comprising a tread portion, a pair of sidewall portions toroidally extending from both sides of the tread portion, a carcass reinforcing the said tread and sidewall portions and composed of at least one ply containing cords arranged in a direction substantially perpendicular to the equational plane of the tire, and a belt disposed between the carcass and the tread portion and composed of a plurality of inextensible cord layers, wherein the tread portion is divided into at least two composite rubber layers in the direction of the thickness thereof, in which an inner rubber layer near to the belt has a dynamic modulus of 100-250 kg/cm^2 and an outer rubber layer has a dynamic modulus of 70-150 kg/cm^2 and a loss tangent of at least 0.25, and the ratio of the dynamic modulus of the inner rubber layer to that of the outer rubber layer is at least 1.15.

The invention is particularly applicable to tires having an aspect ratio of not more than 70%, preferably 60%, more preferably 50%.

The invention will be further described, by way of example only, with reference to the accompanying drawing, which is a right half cross-sectional view of an embodiment of a pneumatic radial tire according to the invention.

The drawing shows a tire 1 wherein a pair of right and left sidewall portions 2 are toroidally connected to both sides of a tread portion 3. Although the left-half section is omitted, the tire 1 is of course symmetrical with respect to an equational plane 0-0.

A bead ring 4 is embedded in an inwardly end part of each of the sidewall portions 2 in the radial direction in a conventional manner, and a carcass 5 extends between both the bead rings 4 to reinforce the sidewall and tread portions.

The carcass 5 is composed of one ply or of a plurality of plies, each ply containing cords of an organic fiber such as polyester fiber, nylon fiber or rayon fiber arranged in a direction substantially perpendicular to the equational plane 0-0. In the illustrated embodiment, the carcass 5 comprises one ply, both end portions of which are wound outwardly around the bead rings 4 to form turnup portions 6, respectively. Further, a hard rubber filler 7 is disposed in a space defined by the carcass 5, turnup portion 6 and bead ring 4 and tapers toward the direction of the tread portion.

The rubber filler 7 is preferably a rubber having a dynamic modulus of 600-1,500 kg/cm^2.

A belt 8 composed of inextensible cord layers is disposed between the carcass 5 and the tread portion 3 in a conventional manner, whereby the rigidity of the tread portion is enhanced as a whole.

The reinforcing element for the belt 8 is a metal cord such as steel or a high elastic fiber cord such as glass, polyester, rayon, or aromatic polyamide. Metal cords or fiber cords may be used alone or there may be used a combination of metal cord with fiber cord. The belt 8 is composed or a plurality of cord layers each containing such cords arranged at an inclination angle of 5°-25° with respect to the equational plane 0-0, the cords of which being crossed with each other.

Although the belt 8 is constructed by merely laminating two steel cord layers 8-1 and 8-2 one upon the other in the illustrated embodiment, there may be used a so-called fold belt structure wherein the cord layer 8-1 is made wider and both side ends thereof are folded and piled on the cord layer 8-2, or a structure wherein one layer or at most two layers containing heat shrinkable fiber cords such as nylon cord arranged

in parallel to or at a slight inclination angle with respect to the equational plane 0-0 may be directly disposed on the belt shown in the drawing to partially or wholly cover it therewith.

The tread portion 3 is composed of a composite rubber layer comprising an outer rubber layer 9 for directly contacting the road surface during running of the tire and an inner rubber layer 10 supporting the outer rubber layer 9 on the belt 8.

The outer rubber layer 9 has a loss tangent (tan δ) of at least 0.25 and a dynamic modulus (E') of 70-150 kg/cm^2, while the inner rubber layer 10 has a dynamic modulus (E') of 100-250 kg/cm^2. The ratio of the dynamic modulus of the inner rubber layer 10 to that of the outer rubber layer 9 is required to be at least 1.15.

The outer rubber layer 9 is a rubber having an improved gripping property against the road surface in addition to wear resistance, and it has been confirmed from experiments carried out by the inventors that when the ratio of the dynamic modulus between the outer rubber layer 9 and the inner rubber layer 10 is as defined above, the gripping property is enhanced together with a suitable flexibility effect of the tread rubber (rib, block, lug) at the ground contact area in the steering during running.

As indicated, the outer rubber layer 9 has a loss tangent (tan δ) of at least 0.25, preferably 0.3-0.5, and a dynamic modulus of 70-150 kg/cm^2, preferably 80-140 kg/cm^2, and the inner rubber layer 10 has a dynamic modulus (E') of 100-250 kg/cm^2, preferably 110-200 kg/cm^2. Further, the ratio of the dynamic modulus of the inner rubber layer 10 to that of the outer rubber layer 9 is at least 1.15, preferably 1.25-2.0. Moreover, as regards a ratio of thickness between the inner rubber layer 10 and the outer rubber layer 9, good results are obtained when the ratio of an average thickness of the inner rubber layer 10 is within a range of 0.15-0.35 relative to that of the outer rubber layer 9. The reason why the thickness of each rubber layer is expressed on average is due to the fact that when the tread portion 3 is composed of, for example, ribs 14 divided by a large number of grooves 13, the joint surface between the inner and outer rubber layers 10, 9 becomes wavy as shown in the drawing.

Though a composite rubber layer composed of two inner and outer layers is shown in the illustrated embodiment, a third or fourth rubber layer may be provided.

As shown in this embodiment, it is preferable that the outer rubber layer 9 and the inner rubber layer 10 are substantially piled one upon the other over the whole of the tread portion, and both side end portions thereof extend in wedge form into rubbers 12 of the sidewall portions having a good flexing property at positions of tire shoulders 11.

Numeral 15 indicates an inner liner having an excellent air impermeability.

In order to confirm the performance of the tire according to the invention, an actual running test was carried out on a circuit course (2.04 km) by using a test tire with a size of 205/60R 15, during which the actual lap time was measured, and also the steering response, stability, wet skid resistance and riding comfort during high-speed running and during running on usual road were estimated by feeling.

Moreover, the feeling during running on the circuit is based on a total evaluation of driving and braking properties, steering response, gripping property against the road surface during steering and controllability beyond slip limit.

As a test tire were used tires A, B and C according to the invention and a control tire D.

All of these tires had a common feature that two rubberized plies each containing polyester cords arranged in a direction perpendicular to the equational plane 0-0 of the tire were wound around the bead ring 4 from inside to outside as shown in the drawing, and the bead filler rubber 7 having a considerably high dynamic modulus was interposed between the carcass ply and its turnup portion. Moreover, as the belt 8, two layers 8-1 and 8-2 each containing metal cords arranged at an inclination angle of 20° with respect to the equational plane 0-0 were laminated so as to cross the cords of these layers with each other as shown in the drawing, and two reinforcing layers each containing nylon cords arranged at an angle of 0° with respect to the equatorial plane 0-0 (not shown) were arranged on each side end portion of the layer 8-2 to particularly reinforce both the side end portions of the belt 8.

The structure and compounding recipe of the tread rubber in each test tire are shown in the following Tables 1 and 2, respectively.

TABLE 1

Kinds of tire	*A*	*B*	*C*	*D*
Tread rubber (Outer rubber layer 9 / Inner rubber layer 10)	W/Z	X/Z	Y/Z	Only W
Average thickness of rubber (mm) (Outer rubber layer 9 / Inner rubber layer 10)	8.0/2.0	8.0/2.0	8.0/2.0	10.0

TABLE 2

Kind of rubber	*W*	*X*	*Y*	*Z*
Butadiene-styrene copolymer rubber (Styrene 23.5%)	50	-	-	100
Butadiene-styrene copolymer rubber (Styrene 35%)	50	100	100	-
Carbon black (HAF)	80	85	-	90
Carbon black (ISAF)	-	-	85	-
Aromatic process oil	40	45	45	35
Stearic acid	1	1	1	1
Antioxidant (IPPD)	1	1	1	1
Zinc white	3	3	3	3
Accelerator				
PPG	0.5	0.5	0.7	0.6
DM	1.0	1.0	0.8	1.2
Sulfur	5	1.5	1.5	1.7
Dynamic modulus (kg/cm^2)	116	97	130	173
Loss tangent	0.340	0.43	0.49	-

Note: The dynamic modulus and loss tangent were measured with respect to a strip specimen of width 5 mm×length 20 mm×thickness 2 mm using a viscoelastic spectrometer made by Iwamoto Seisakusho under the test conditions of a frequency of 50 Hz, a dynamic strain of 1% and a temperature of 25°C.

The test tire assembled onto a rim and subjected to an internal pressure of 2.2 kg/cm^2 was mounted on a vehicle and actually run to obtain results as shown in the following Table 3.

TABLE 3

Kind of tire	*A*	*B*	*C*	*D*
Running lap-time (circuit)	1′ 15″ 81	1′ 15″ 10	1′ 14″ 70	1′ 16″ 25
Running feeling (circuit)	104	105	107	100
Steering response	104	105	106	100
Stability	105	105	107	100
Wet skid resistance	100	103	104	100
Riding comfort against vibration	100	100	99	100

Note: The properties other than the lap time are expressed as an index when the tire D is regarded as 100. The larger the index value, the better the property.

As mentioned above, according to the invention, the steering response during high-speed running can be considerably improved.

CLAIMS

1. A pneumatic radial tire, comprising a tread portion, a pair of sidewall portions toroidally extending from both sides of the tread portion, a carcass reinforcing the said tread and sidewall portions and composed of at least one ply containing cords arranged in a direction substantially perpendicular to the equational plane of the tire, and a belt disposed between the carcass and the tread portion and composed of a plurality of inextensible cord layers, wherein the tread portion is divided into at least two composite rubber layers in the direction of the thickness thereof, in which an inner rubber layer near to the belt has a dynamic modulus of 100-250 kg/cm^2 and an outer rubber layer has a dynamic modulus of 70-150 kg/cm^2 and a loss tangent of at least 0.25, and the ratio of the dynamic modulus of the inner rubber layer to that of the outer rubber layer is at least 1.15.

2. A pneumatic radial tire as claimed in claim 1, wherein the said outer rubber layer has a dynamic modulus of 80-140 kg/cm^2 and a loss tangent of 0.3-0.5.

3. A pneumatic radial tire as claimed in claim 1 or 2, wherein the said inner rubber layer has a dynamic modulus of 110-220 kg/cm^2.

4. A pneumatic radial tire as claimed in any of claims 1 to 3, wherein the said ratio of the dynamic modulus of the inner rubber layer to that of the outer rubber layer is within a range of 1.25-2.0.

5. A pneumatic radial tire as claimed in any of claims 1 to 4, wherein the ratio of the thickness of the inner rubber layer to that of the outer rubber layer is within a range of 0.15-0.35 on average.

6. A pneumatic radial tire according to claim 1, substantially as herein described with reference to, and as shown in, the accompanying drawing.

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